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IFM-GEOMAR Report 2002-2004

From the Seafloor to the Atmosphere

- Marine Sciences at IFM-GEOMAR Kiel -

Institut für Meereskunde Kiel

GEOMAR

June 2005

Preface

For the first time, the Leibniz Institute of Marine Sciences (IFM-GEOMAR) presents a joint report of its research activities and developments in the years 2002-2004. In January 2004 the institute was founded through a merger of the former Institute for Marine Research (IfM) and the GEOMAR Research Center for Marine Geosciences. This report addresses friends and partners in science, politics and private enterprises. It gives an insight into the scientific achievements of IFM-GEOMAR and its predecessor institutes during the last three years.

3.12 The Hikurangi Oceanic Plateau: A Fragment of the Largest Volcanic Event on Earth

The Hikurangi oceanic plateau is located in the southwest Pacific off the east coast of New Zealand. The portion of the plateau exposed on the seafloor covers an area of 350,000 km^2, similar to that of New Zealand (Fig. 1a). If subducted portions beneath the North Island of New Zealand and the submarine Chatham Rise, imaged with geophysical techniques, are included, the plateau covers at least 800,000 km^2. New bathymetric, age and geochemical data obtained during the *ZEALANDIA* cruise with the German research vessel Sonne indicate that the plateau formed during the Greater Ontong Java Event (ca. 122 m.y. ago), the largest-known volcanic event on Earth. With the inclusion of the Hikurangi Plateau, this submarine event covered ~1% of the Earth's surface with volcanism possibly within a few million years and appears to have had dramatic impact on the chemistry, temperature and life of the Earth's oceans.

Large Igneous Provinces (LIPs), which represent large regions of the Earth's surface (in some cases thousands of kilometers across) covered by volcanism, include oceanic plateaus (e.g. Ontong-Java and Caribbean) and continental flood basalt events (e.g. Siberian and Deccan Traps). The formation of large igneous provinces has fundamental implications for the transfer of mass and energy from the interior of the Earth to its surface and for the growth and breakup of continents. These massive volcanic outpourings have occurred contemporaneously with all major mass biotic extinction events on Earth, suggesting a causal link. There is no doubt that they also contributed to global environmental change.

Many LIPs appear to have primarily formed over relatively short geological time intervals (several million years). The most widely accepted model to explain the large volume, wide geographic distribution, and short time interval of LIPs is that they are formed through mantle upwellings (plumes) with large mushroom-shaped heads at their initiation. Upon reaching the base of the lithosphere, these plume heads can flatten into disks with diameters exceeding 2000 km, generating widespread volcanism. Recently alternative models have been proposed to explain some LIPs. For example, it has been proposed that the Ontong Java plateau was formed as a result of a meteoritic impact and that the Caribbean Large Igneous Province formed through accumulation of intra-plate volcanism over at least 70 m.y. and terrane accretion during the subduction process.

In contrast to continental LIPs, relatively little is known about oceanic LIPs, due to their relatively inaccessable location on the seafloor. We are investigating the Hikurangi Plateau and have future plans to investigate the Manihiki Plateau, in order to gain new insights into the age, surface and internal structure, chemical composition, origin and evolution of oceanic plateaus, which form the most voluminous LIPs on Earth. Two major models have been proposed for the origin of the Hikurangi Plateau. 1: The plateau formed as part of a massive volcanic outpouring associated with a plume head that triggered the final break-up of the Gondwana super-continent (consisting of Antartica, Africa, South America, India, Australia and the New Zealand micro-continent Zealandia) ca. 100 m.y. ago). 2: The plateau formed as part of the greater Ontong Java flood basalt event ca. 122 million years ago. In accordance with the second hypothesis, the Hikurangi Plateau may have once been connected to the Manihiki oceanic plateau (now located more than 3000 km to the north) but separated in the Cretaceous by seafloor spreading at the Osbourn Trough, a paleo-spreading center (Fig. 1a). The Manihiki Plateau (ca. 122 million years) formed as a separate plateau during the greater Ontong Java volcanic event.

In order to test these hypotheses, we carried out detailed bathymetric (depth) mapping and sampling of the Hikurangi Plateau during the *ZEALANDIA* expedition. This research cruise yielded the most detailed bathymetric maps, used to evaluate the structure and volcanic evolution of the plateau, and rock collections, used for age dating and geochemical analyses, of an oceanic LIP to date. The new bathymetric maps reveal spectacular views of one of these massive volcanic outpourings on the seafloor, providing new insights into the geodynamic evolution of an oceanic plateau. The mapping for example confirmed the rifted nature of the

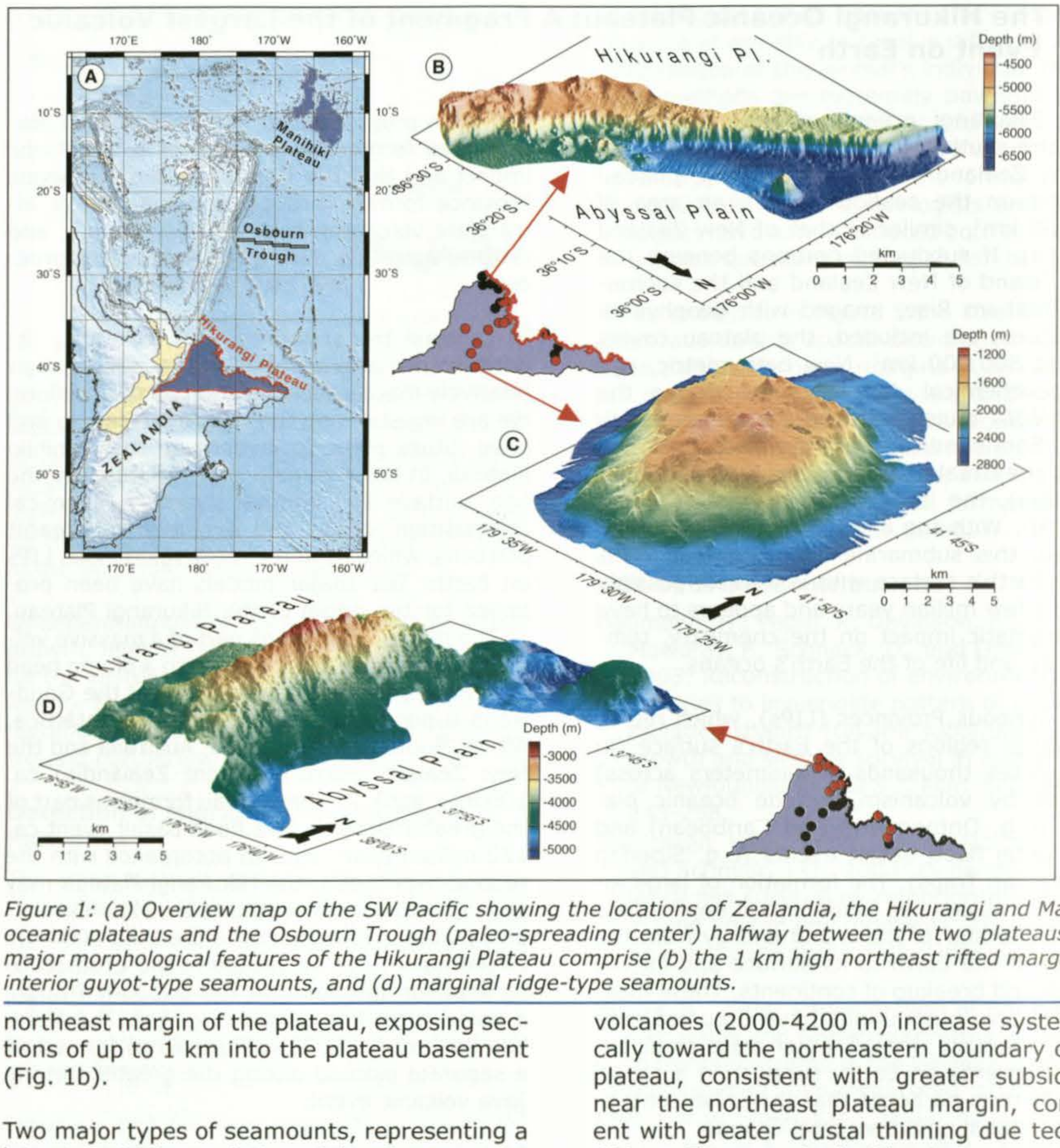

Figure 1: (a) Overview map of the SW Pacific showing the locations of Zealandia, the Hikurangi and Manihiki oceanic plateaus and the Osbourn Trough (paleo-spreading center) halfway between the two plateaus. The major morphological features of the Hikurangi Plateau comprise (b) the 1 km high northeast rifted margin, (c) interior guyot-type seamounts, and (d) marginal ridge-type seamounts.

northeast margin of the plateau, exposing sections of up to 1 km into the plateau basement (Fig. 1b).

Two major types of seamounts, representing a late stage in the evolution of the plateau, were identified: 1) large guyot-type seamounts in the interior of the plateau (Fig. 1c), and 2) ridge-type seamounts along the margin of the plateau (Fig. 1d). The most striking feature of all the interior seamounts is their guyot-like form, characterized by circular, steep-sided bases and relatively flat tops, ~1 km above the plateau basement and up to 24 km across (Fig. 1c). The mapping and recovered samples are consistent with the seamounts being former island volcanoes that were eroded to sea level. The depth of both the erosional platforms (1600-3300 m) and the base of the volcanoes (2000-4200 m) increase systematically toward the northeastern boundary of the plateau, consistent with greater subsidence near the northeast plateau margin, consistent with greater crustal thinning due tectonic rifting. The marginal ridge-type seamounts comprise elongated linear features with sharp, ridge-like tops (Fig. 1d). These seamounts occur exclusively along the northeast margin of the Hikurangi Plateau and are sub-parallel to the plateau margin. The ridge-type seamounts reach elevations of ~1.5 km above the seafloor, which exceeds the height of the erosional platforms on the guyots. Therefore at least the latest stages of volcanism on the ridge-type seamounts formed after the interior guyot-type seamounts were eroded and began to subside. The linearity of these ridge-type seamounts, their proximity to the northeast margin and

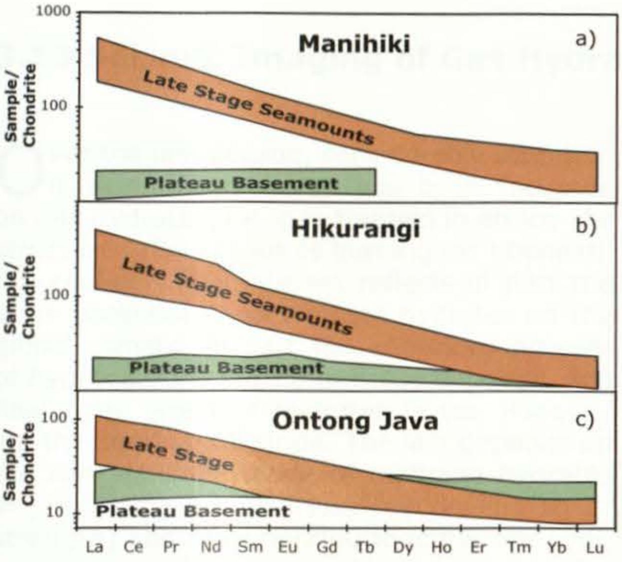

Figure 2: Chondrite-normalized Rare Earth Element (REE) patterns of volcanic rocks from the a) Manihiki, b) Hikurangi and c) Ontong Java Plateaus. The plateau basement in all three oceanic plateaus is characterized by tholeiitic volcanism and displays similar trace element characteristic, for example, flat REE patterns. A late stage of volcanism formed seamounts of alkalic composition on the Manihiki and Hikurangi plateaus. Within the Ontong Java Plateau a late alkalic phase with enriched REE patterns has also been identified (Sigana Alkali Basalts on Isabela Island). Data sources for Manihiki and Ontong-Java are from the literature and GEOROC (http://georoc.mpch-mainz.gwdg.de/).

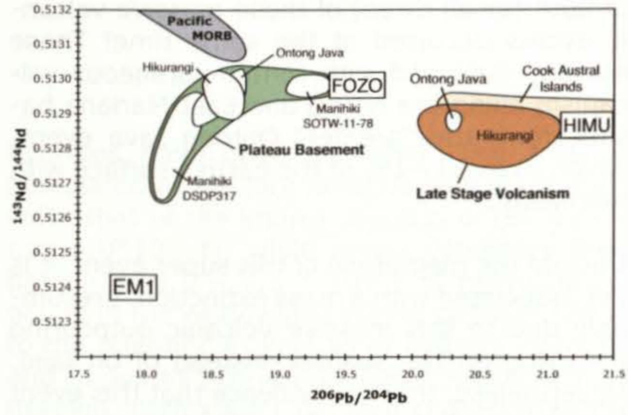

Figure 3: $^{143}Nd/^{144}Nd$ - $^{206}Pb/^{204}Pb$ isotope correlation diagram for volcanic rocks from the Hikurangi, Manihiki and Ontong Java Plateaus. The basement for all three plateaus has similar Nd and Pb isotopic compositions and overlaps the field for Pitcairn Island, characterizing enriched (EM1)-type mantle. Alkali basalts from the late magmatic stage of the Hikurangi and Ontong Java Plateaus also have similar Nd and Pb isotopes, overlapping the field for HIMU (high time-integrated $^{238}U/^{204}Pb$) type compositions from the Cook Austral Islands. The similarity in geochemistry between the three oceanic plateaus and volcanism associated with ocean island hotspot volcanoes, instead of Pacific mid-ocean-ridge basalt (MORB) which represents the composition of the upper mantle, favors an origin of the greater Ontong Java event as a result of a deep-seated mantle plume rather than through melting triggered by a meteoritic impact. Data sources are the same as in figure 2.

their orientation sub-parallel to the margin suggest that these seamounts occur in association with extensional faults, formed during the rifting event.

Igneous rocks were recovered from 77 sites on the Hikurangi Plateau, including the plateau basement and both types of seamounts. $^{40}Ar/^{39}Ar$ age dating shows that the plateau basement formed between ca. 100-120 m.y. and the guyot-type seamounts between ca. 86-99 m.y. The plateau basement rocks have tholeiitic compositions, whereas the late-stage seamount lavas have more SiO_2-undersaturated compositions, suggesting formation through lower degrees of melting during the waning stage of plateau formation. Trace element and Sr-Nd-Pb isotope data show that the plateau basement was derived from an enriched mantle (EM) source, similar in composition to the Ontong Java and Manihiki Plateaus; whereas the large alkalic guyots on the plateau were derived from a distinct high $^{238}U/^{204}Pb$ (HIMU) mantle source, similar to alkalic dikes (90 m.y.) on the Ontong Java Plateau and possibly to alkalic seamounts (ca. 75-86 m.y.) on the Manihiki Plateau (Fig. 2, 3). Therefore all three platforms appear to have had similar temporal and geochemical evolutions consistent with a common origin for all three plateaus. More work, in particular on the age and compositions of seamounts on the Manihiki Plateau, are however necessary to confirm this conclusion. A cruise with *R/V SONNE* to the Manihiki Plateau is planned for spring of 2007 to carry out detailed bathymetric mapping and sampling of the plateau basement and the late-stage seamounts.

Similar temporal and geochemical evolution and bathymetric data indicating that the NW Hikurangi margin is a rifted margin support the hypothesis that the Hikurangi and Manihiki Plateaus may have once formed a combined Hikurangi/Manihiki (HikuMani) plateau. This combined plateau could have covered an area of ≥1.3 million km², making it (at least) the second largest plateau (LIP) on Earth after the Ontong Java Plateau (1.5 million km²). What is even more exceptional is that the main phase of both (or all three) of these massive volcanic events occurred at the same time! These events, combined with contemporaneous volcanism filling the Nauru and East Mariana basins, form the "greater" Ontong Java event, which covered ~1% of the Earth's surface with volcanism.

Despite the magnitude of this super event, it is not associated with a mass extinction, presumably due to this massive volcanic outpouring occurring on the seafloor instead of on land. Nevertheless, there is evidence that this event had a global impact on the chemistry, temperature and life in the Earth's oceans, since it appears for example to be closely correlated with the early Aptian "nannoconid crisis", global ocean anoxic event OAE1a ("Selli" black shale level) and global changes in seawater Sr isotopic compositions.

IFM-GEOMAR Contributions

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